

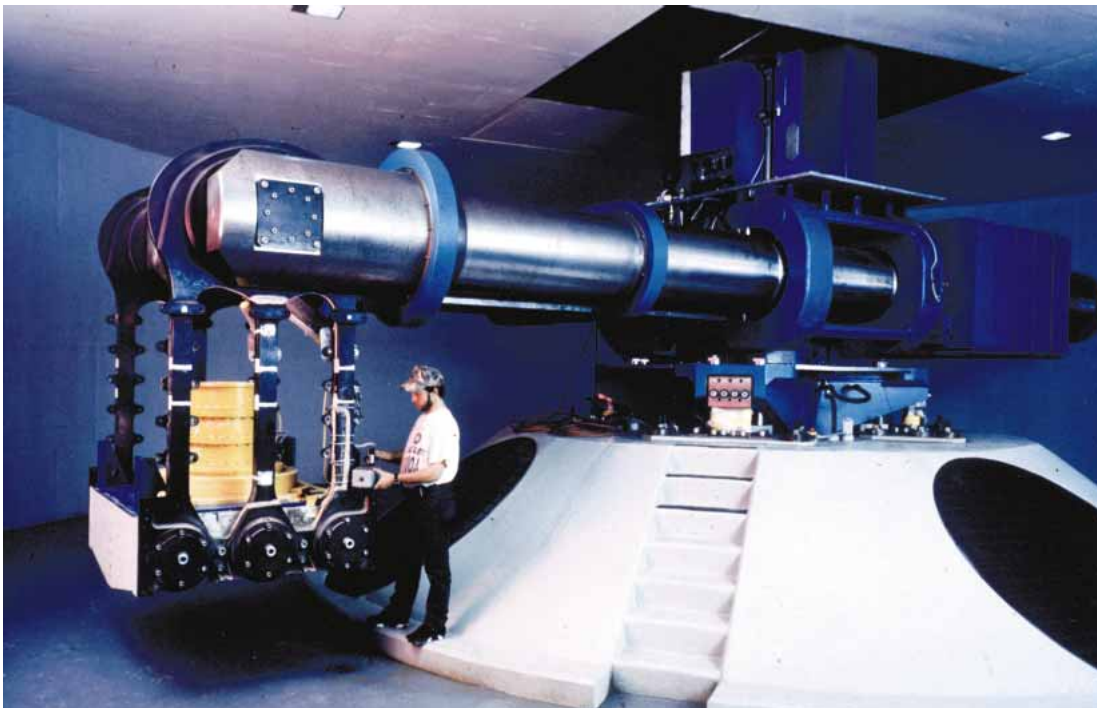
Geotechnical Laboratory

In the WES Geotechnical Laboratory, engineers and scientists are developing innovative solutions to a broad spectrum of problems, ranging from earthquake engineering to combat mobility. The Geotechnical Laboratory is the Department of Defense research leader for Airfields and Pavements and Sustainment Engineering under Defense Science and Technology Reliance.

Unique facilities include a 5,580 square-meter Indoor Pavement Research Facility, a 1.1 kilometer Pavement Test Track, 988 hectares for off-road mobility tests, a 6,975 square-meter Trenchless Technology Test Facility with six distinct soil profiles, a 1.5-meter-diameter calibration chamber, and a 1,395 square-meter Environmental Geophysics Test Facility. The Geotechnical Laboratory also houses the Airfields and Pavements Research Center and the Soils Research Center, each equipped with custom-built and state-of-the-art laboratory equipment, including equipment for testing of large-diameter specimens.

World's Most Powerful Centrifuge. The research activities of the U. S. Army's Centrifuge Research Center began in 1996 using the unique Acutonic 684-1 centrifuge, which has a design rating of over 1,144 g-metric-tons. This apparatus, which scales the effects of gravity and gravity-related processes in physical models, possesses capabilities applicable to many engineering fields.

In FY 97, a series of demonstration experiments were conducted in the fields of blast effects (crater formation), geotechnical (stability of silt slopes), hydraulics (groundwater models of immiscible flow), and environmental (consolidation of dredged disposal). Experiments are under way in earthquake modeling, pavement deformation, and coastal engineering. In late FY 97, the centrifuge set world records for both maximum payload and payload acceleration (8.2 metric tons at 150 g's and 1.8 metric tons at 350 g's).



The U.S. Army Research Centrifuge

Information Analysis Centers. The Geotechnical Laboratory is the home of the Airfields, Pavements, and Mobility Information Analysis Center and the Soil Mechanics Information Analysis Center. The Centers collect, analyze, and disseminate scientific and technical information in their specialized areas. The Information Analysis Centers provide immediate contact with subject matter experts and access to a multitude of reference materials. During the year, these centers supplied information in response to several hundred requests received from across the nation.

Geophysical Investigations. A geophysical technique, micro gravity, was used to determine densities of strategic heavy metal ore stock piles in the Defense National Stockpile. These densities were used in conjunction with the stock pile volumes to confirm the available supplies of the various strategic ores. This work was sponsored by the Defense National Stockpile Center.

The research vessel WATERWAYS EXPLORER served as a platform for an integrated geophysical system consisting of subbottom profiling and side-scan sonar equipment. Results assisted in determining disposal locations of dredged material in New York Harbor, planning channel deepening operations in Newark Bay, and characterizing subbottom sediments at Pipe Flat and Success Dams for input to seismic safety evaluations.

WES performed other geophysical investigations using electromagnetic, magnetic, and ground penetrating radar methods to locate archeologically important sites, landfills, detect anomalies causing security cable problems, to characterize unexploded ordnance research sites for background “noise” determinations, and to help locate illegal drug traffic tunnels under the U.S.-Mexico border.

Earthquake Engineering. WES is conducting a major effort to improve the safety of the nation’s dams, locks, and levees located in earthquake prone regions, but built before seismic hazards were recognized or understood.

Two hundred Corps dams and 73 intake towers have been identified as subject to severe earthquake shaking.

Development of the Earthquake Engineering Research Program involved coordination among eight federal agencies, key universities, and international experts. The multi-year program includes elements to remediate and improve the design of both concrete and embankment dams. The program offers vast cost savings by focusing research to optimize seismic remediation efforts that will protect lives and minimize the devastation of earthquake events.

Conceptual Hydrogeologic Model.

Aberdeen Proving Ground (APG) covers almost 125 square miles of land and water that are superimposed on complicated subsurface geological conditions. APG installation restoration has focused on identification of contaminants and treatment technologies for small, specific sites. This approach addressed the regulatory structure, but led to remediation decisions that did not address the reality of the installation’s complex problems.

APG has contaminants from multiple sources that move along multiple natural and man-made pathways and interact in ways that are largely



Downloading data from hydrogeology study well, Aberdeen Proving Ground

controlled by little-known geologic features in the shallow subsurface. WES scientists developed a regional conceptual model of the geology and hydrogeology of APG in FY 97 in cooperation with an interdisciplinary team from the Corps' Baltimore District, U. S. Geological Survey, and the Maryland Geological Survey. The model uses geographic information systems (GIS) to compile data from nearly 2,000 wells and geologic borings. The data includes well locations, water elevations, and geologic features correlated between borings. Within the GIS, researchers can relate these data to locations of trenches and landfills and to locations and pumping rates of various public water well fields. The conceptual geological model, recently published in a WES report, is the framework for relating the locations and movements of groundwater to geological and man-made controls. The model provides a regional approach to identify pathways by which contaminants might affect people and is the cross-agency key to cost-effective remediation strategy.

Large Scale Test Cell. This is the largest test cell of its type in the world (1.5 meters in diameter and 1.8 meters high). The test cell was developed to investigate complex soil-structure interaction problems that cannot be modeled or studied by other means. Unique features include 1.5 MPa maximum vertical stress, 1.0 MPa maximum lateral stress, and complete internal instrumentation. Soil specimens can be back pressure saturated, and hydraulic gradients can be applied across the specimen both vertically and horizontally. In FY 97 the test cell was used to produce the first reliable cone penetration results ever obtained in gravels.

The Materials Testing Center (MTC). The MTC is the Corps' designated testing center for soil, rock, concrete, asphalt, and materials. It has the capabilities for all conventional material tests, can meet any specialized testing requirements, and has access to the largest and most comprehensive testing and analytical support facility in the world. Some of the MTC's unique equipment includes: a closed loop electro-hydraulic loading system with five frames (two of the frames can test soil specimens up to 18 inches in diameter), a directional shear cell,

a two-foot-diameter direct shear device, a 2.4 million pound capacity Universal Testing Machine, a variable-pressure scanning electron microscope, and facilities for the Strategic Highway Research Program (asphalt binder testing and mix design). The MTC is also the Corps' corporate resource for inspections and certification of commercial laboratories for quality assurance and quality control testing.

Radioactive Waste Recovery. The Savannah River site has 51 tanks that contain high level radioactive waste created from fuel reprocessing activities. These tanks hold approximately 30 million gallons of waste in the form of sludge, liquid, and salt that must be converted into more stable waste forms for long-term storage. A theoretical study determined the degree to which Cesium-137 could be removed from the salt-filled tanks, which would greatly reduce costs, by displacing interstitial water prior to dissolving the salt. Numerical simulations of the salt removal process were performed at WES with the Department of Defense Groundwater Modeling System.

Innovative Alternatives to Conventional Levees and Levee Rehabilitation. Although the earth embankment levees that have been designed, constructed, and maintained by the Corps of Engineers provide cost-effective and reliable flood protection for many areas, they cannot be used in all locations. In other cases, levees cannot be raised or rehabilitated economically. Research efforts to identify innovative alternatives to conventional levees and levee rehabilitation techniques are underway at WES.



Materials Testing Center

Efforts involve assessing the state-of-the-art and the state-of-practice with regard to innovative concepts for flood protection. Reports concerning use of polymeric fibers in clays and use of composite drainage systems were published in FY 97. Additional applications guidance is being developed.

Soil Investigations for Soil-Bentonite Cutoff Wall. The Soils Research Facility at WES is performing a laboratory investigation for the design of a soil-bentonite cutoff wall at the Wyckoff Superfund Site near Puget Sound, Wash. This work is sponsored by the Corps' Seattle District. The soils and groundwater in the water table aquifer at the Wyckoff site were contaminated as a result of wood treatment operations formerly conducted at the site.

The laboratory investigation will provide data needed to evaluate and select suitable materials for the design and construction of the cutoff wall. The program is evaluating the ability of bentonitic materials to resist the flow of water and withstand the chemical attack of the contaminants. The project is a joint effort between the Geotechnical Laboratory and the WES Environmental Laboratory, which is responsible for analysis to determine contaminant levels in the site's groundwater.

Directional Drilling. WES and private industry partners successfully completed the field portion of the Construction Productivity Advancement Research project "Guidelines for the Installation of Pipelines Beneath Levees Using Horizontal Directional Drilling."

The field work involved installing three pipelines beneath a Mississippi River levee using horizontal directional drilling. During the installation, drilling fluid pressures and weights were systematically varied to represent a wide range of drilling conditions. Piezometers and down-hole pressure tools were carefully monitored during the drilling to establish maximum safe drilling pressures and minimum safe depths for drilling under levees and other Corps structures.

An autopsy was made by exposing the pipelines from the surface after the construction was completed. This autopsy allowed visual identification of the "zone of influence" around the pipeline created by the drilling fluids.

Guidelines were developed to assist Corps' districts and private industry in evaluating proposals for levee crossings. The guidelines focus on issues that should be addressed for a successful crossing while ensuring the continued safety of Corps flood protection projects.



Aerial view of the Directional Drilling Test Site

Groundwater Model for Ft. Lauderdale Water Supply. The Peele-Dixie well field is one of two major drinking water well fields for the city of Ft. Lauderdale, Fla. In 1986, volatile organic compounds above acceptable drinking water levels were discovered in some of the wells within the well field. A remedial investigation, sponsored by EPA, was conducted by the Bechtel Corporation. This investigation concluded that the Florida Petroleum Reprocessors site was the most likely source of the 500-acre plume impacting the well field.

The site is now a Superfund site with approximately 40 possible responsible parties. These parties claim that the North New River Canal (which lies between the Florida Petroleum Reprocessors site and the well field) acts as a groundwater divide, and therefore it is unlikely that contamination from the Florida Petroleum Reprocessors site would transect the canal or pass beneath it.

The EPA contacted the Geotechnical Laboratory to develop a geohydrologic conceptual and numerical model of the well field. The model will simulate actual stresses applied to the aquifer during the period the Florida Petroleum Reprocessors site was operational. The well field capture zones simulated by the model could then estimate the likelihood of water traveling from that site to the well field. The model will be completed in FY 98. The results from the model will help determine liable parties for the clean up of the contaminant plume.

Military Vehicle Mobility Assessments.

Mobility performance evaluations of military vehicles help U.S. military commanders maintain their edge in battlefield maneuver capabilities. Variants of the Palletized Load System, Bradley Fighting Vehicle, the M88A2 tank retriever and a family of medium tactical vehicles were among the U.S. vehicles evaluated by WES during FY 97.

Palletized Load System. The Palletized Load System was evaluated using a WES designed payload simulator and high fidelity dynamic instrumentation package to determine the dynamic handling characteristics of the system in relation to the palletized load's location. Theoretical algorithms were designed from the program results and are being implemented into an automated weigh system for next generation of Palletized Load System vehicles.

Terrain Induced Vehicle Vibration Tests.

Experiments using the WES Vibration Meter were conducted on heavy wheel vehicles to develop modeling relationships between the terrain roughness and vibration energy experienced by the vehicle. These algorithms will be used

in modeling efforts to better define vehicle induced terrain degradation and military vehicle mission performance and requirements.

Semi-Active Trailing Arm Suspension

Experiments. Research with a semi-active suspension was conducted by WES engineers using the Bradley Fighting Vehicle. Handling, ride quality, and shock response tests were conducted to quantify the response of the semi-active suspension. Standard vehicle suspension tests were conducted alongside the semi-active vehicle tests to develop performance comparison relationships.



Bradley Fighting Vehicle with semi-active suspension used in vehicle vibration experiments

Track System Design. Heavy tank track design research was carried out using the M88A2 Hercules tank retriever. Traction analyses were conducted over two different soil types to determine the relationship between different track designs and performance. Empirical relationships were created and implemented in the NATO Reference Mobility Model to better explain M88A2 mission performance.

Foreign Vehicle Tests. Several foreign vehicle exploitation programs were conducted for the National Ground Intelligence Center to determine the mobility and ride characteristics of different vehicle systems. These vehicles included a Russian missile transporter, a British armored personnel carrier, and a Russian tank transporter. The results of these programs are used to better define the mission capabilities of other forces around the world and to project counter mobility measures.

Engineer Operations Software. As part of the Corps' Technology Base Demonstration Program, three maturing WES research products, the Obstacle Planning Software, the Simplified Survivability Assessment Module, and the initial Battle Tracking Module with HORNET performance algorithms, were integrated with the Army Common Operating Environment's Terrain Evaluation Module into the WES-developed Engineer Operations (EOPS) software.

The Engineer Brigade of the 4th Infantry Division used EOPS during the Division XXI Advanced Warfighting Experiment at Fort Hood, Texas, to perform engineer planning and battle tracking. EOPS is interoperable with the Maneuver Control System and All Source Analysis System and can provide an engineer overlay to maintain situational awareness with the Army Battle Command System. As a result, the U.S. Army Engineer School has accepted EOPS as the baseline for the Tactical Engineer Command and Control System.

Vehicle-Terrain Interaction. WES has developed and validated algorithms which infer mobility factors based on standard digital data for worldwide application. In conjunction with this effort, WES has also developed techniques to estimate soil strength worldwide for military

operations based on soil type, climatic influences (temperature, precipitation, evaporation, etc.), and related soil moisture. These techniques are incorporated into the current version of the Soil Moisture-Strength Prediction Model (SMSP II). SMSP II was used with the NATO Reference Mobility Model to forecast off road trafficability of U.S. vehicles during Operation Joint Endeavor (Bosnia) in early FY 97.

Obstacle Planner Software. A team of WES engineers provided support to the 412th Engineer Command, Combined Forces Command Engineer (CFC-ENG), and Army Air Missile Defense Command during the ULCHI FOCUS LENS 97 exercise, the annual command post exercise involving Combined Forces Command and the Republic of Korea. Analytical products were generated using the Obstacle Planner Software (OPS) for mobility, counter mobility, mission planning, engineer task organization, and theater missile defense support.

The current OPS software is capable of generating standard military messages for transmission of critical battlefield geometry and planning information to other command and control systems such as Maneuver Control System and All Source Analysis System.

Countermining Foam. Experiments were conducted by WES for the Maneuver Support Battle Laboratory to test the feasibility of using rigid polyurethane foam as a countermining measure and to increase the traction of wheeled and tracked vehicles in wet slippery conditions.



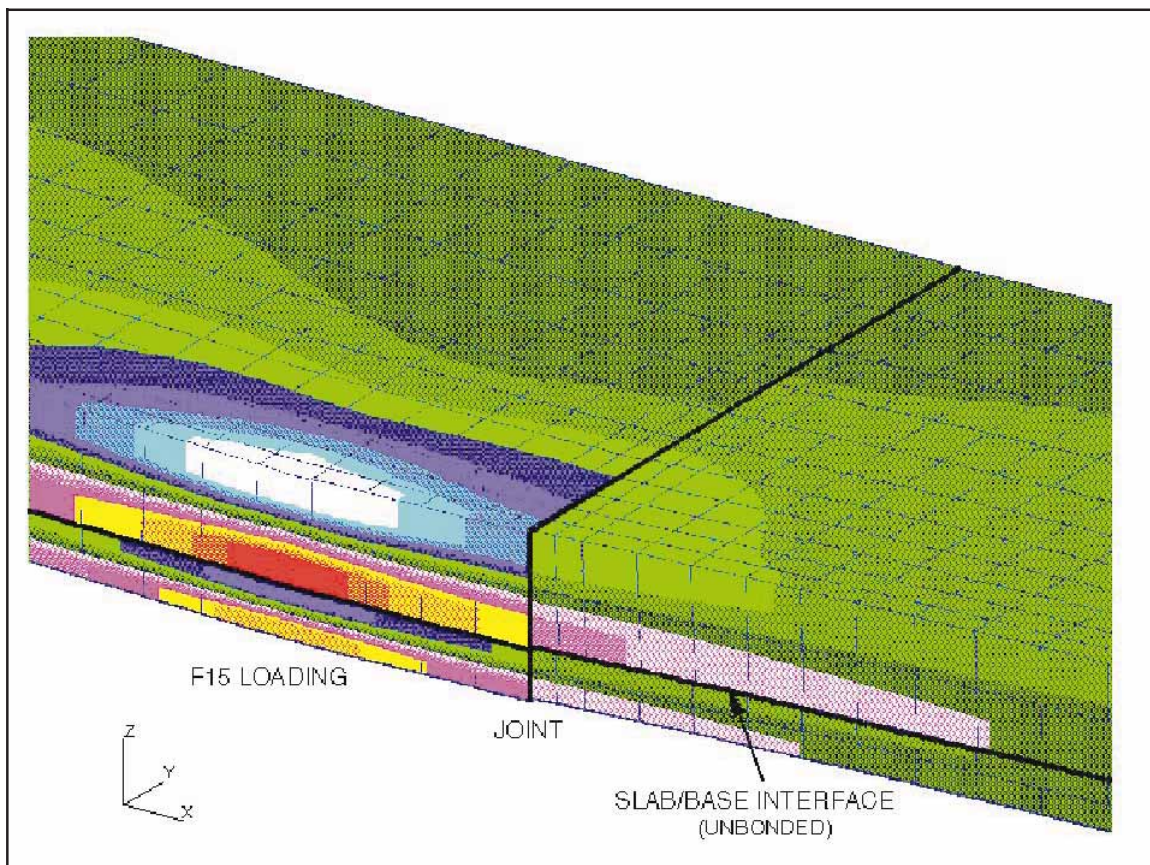
M88A2 tank retriever making an evaluation run on a section of countermining foam

Application of the foam to a thickness of 60 centimeters appeared to neutralize most anti-tank mines but triggered all trip wire devices that were placed in the test lane. The foam also appeared to stand up well under vehicle traffic. Traction of the M88A2 (tracked) decreased with the application of the foam while the HMMWV (wheeled) showed moderate improvement of traction. As currently configured, the foam has severe shortcomings with respect to rapid deployment.

Computerized Pavements Modeling. Pavement engineers in the Geotechnical Laboratory are developing comprehensive structural design and analysis models for both flexible and rigid pavements. The result will be an incremental procedure where significant features of pavement response are identified, characterized, and modeled. The models will be verified with both historical and new accelerated traffic test section data.

This project also involves the development of theoretically sound, rational, and consistent constitutive models that can capture the fundamental response characteristics of pavement materials. These models will be formulated for implementation in high performance computational modeling procedures such as the finite element method. Basic mechanisms of permanent plastic deformation, moisture effects, cyclic loading, and shear dilation will be examined and covered in the models.

C-17 Airfield Research. The C-17 advanced military airlift aircraft is designed to support contingency operations through its capability of operation on short, austere airfields. These airfields often are not paved, requiring the C-17 to operate on soil surfaces. The C-17 System Program Office requested that WES help determine the impact of the C-17 on contingency airfields and verify criteria for designing unsurfaced airfields for this aircraft.



Results from finite element model of concrete pavement under F-15 aircraft loading



C-17 operating on an unsurfaced airfield

Because the C-17 has a unique main landing gear configuration, the extrapolation of existing structural criteria for designing C-17 capable airfields required field testing. WES constructed full scale pavement items and evaluated to failure. A matrix of material strengths and thicknesses provided data for verifying and modifying the existing criteria.

WES also supported field operations of the C-17 on selected airfields. This included evaluating airfield performance and the impact of the airfield roughness on the aircraft. Material parameters, unsurfaced pavement performance, and longitudinal profiles were measured before, between, and after C-17 operations. The measured material parameters and airfield performance provided input to the structural model. The longitudinal profile measurements provided data for the roughness model, which relates the airfield profile to the loads imposed on the aircraft. If these loads become critical, the airfield will require maintenance and/or reconstruction to provide the smoothness necessary to safely operate the aircraft.

The WES research will provide more reliable design, evaluation, and performance models for predicting the performance of the C-17 on

unsurfaced airfields, expanding the mission capabilities of the aircraft while ensuring safety and operational requirements.

Micro-Surfacing. WES researchers developed design and application criteria for an important new pavement technology known as micro-surfacing. Micro-surfacing is a flexible pavement maintenance technique similar to slurry seal surface treatment except that micro-surfacing uses a polymer-modified binder and higher-quality, larger aggregates. The polymer additive and larger aggregates allow for thicker, more durable applications. The new technology will be an important, cost-saving pavement maintenance technique for military installations and government agencies seeking to protect their valuable pavements infrastructure.

WES engineers helped to demonstrate the usefulness of micro-surfacing by aiding in the design and construction of a full-scale pilot project on the main runway at MacDill Air Force Base in Florida. Although structurally sound, the runway surfacing had weathered to the point where normal aircraft operations were dislodging surface aggregates from jet engine blasts. The micro-surfacing at this site has provided a smooth and durable runway surfacing

and saved considerable construction time and costs when compared to the standard hot-mix asphalt overlay technique.

Instrumentation of Rigid Pavements at Denver International Airport. The verification of existing pavement design and the development of new pavement design methods are performed by WES through the use of in-place pavement instrumentation. Through funding from the Federal Aviation Administration, WES Geotechnical and Information Technology Laboratories personnel designed and installed an elaborate instrumentation system at the Denver International Airport. This instrumentation system monitors pavement response and performance as influenced by aircraft loadings and environmental changes.

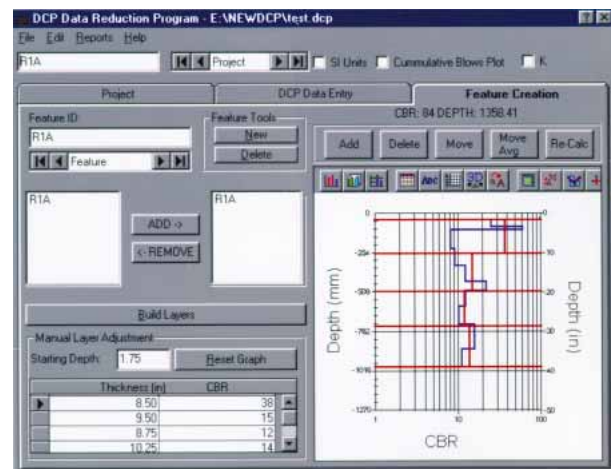
In FY 97, WES analyzed pavement response measurements collected at Denver International Airport from several military cargo aircraft in an effort funded by the U.S. Air Force. The research identified significant changes needed in design and evaluation procedures for military rigid airfield pavements. WES is at the leading edge for technology transfer in the arena of rigid airfield pavement instrumentation. The Air Force has programmed funding for WES to verify existing pavement design and evaluation methods for flexible airfield pavements.

Pavement-Transportation Computer Assisted Structural Engineering (PCASE). PCASE was established to develop and provide computer programs for designing and evaluating transportation systems. PCASE programs include rigid and flexible airfield design by conventional and layered elastic methodologies, rigid and flexible road design, and pavement and railroad evaluation programs. When these programs are approved, they are distributed via appropriate Corps of Engineers documents and by inclusion in Technical Manuals. The latest versions of all WES PCASE programs are available to users 24 hours a day via the WES Airfields & Pavements Division web site (<http://pavement.wes.army.mil>). Most PCASE products are being converted into 32 bit Windows 95/NT software packages.

Sand-Fiber Stabilization. WES developed a new sand-fiber stabilization technique using polypropylene fibers to expediently construct military supply roads over-the-beach or across desert sands.

Full-scale concept development experiments were used to validate construction procedures and the load carrying capabilities of the new concept. A comprehensive laboratory study was conducted to investigate variables such as sand type, silt content, fiber types, fiber lengths, fiber shapes, and fiber contents on load carrying performance. Full-scale sand-fiber experimental roads were constructed based on laboratory results and trafficked using a heavily-loaded military truck. A wearing surface incorporating an environmentally friendly resin-modified emulsion added to the durability of the road surface. A total of 10,000 truck passes were applied without requiring any roadway maintenance.

Results showed that as little as 0.8 percent fiber was sufficient for stabilizing a wide range of sand types. This new technology offers military engineers a 50 percent faster method of constructing heavy-duty supply roads over sands while using less manpower and no new equipment.



PCASE program output from WES Win 95/NT for the Dynamic Cone Penetrometer Program

Lightweight Mat Roadways. The military needs lightweight matting materials for expedient construction of access roads, parking areas, and sidewalks. WES investigated several lightweight mat materials and found three that have great potential for military applications. Two of the mats are manufactured in Germany and are now commercially available in the United States. The mats have interlocking 0.25-square-meter hexagonal panels made of aluminum or plastic. The plastic hex mats weigh only 3.2 kilograms per panel and can be installed quickly using non-engineer troops.

WES is also developing a fiberglass mat (each panel is 1.2 meters by 3.6 meters by 10 millimeters) for quick installation on roadways, storage areas, or aircraft parking aprons.



Plastic hex mat with only 5.8-centimeter rut after 5,000 passes

All three mats are reusable and will cut cost and installation time by more than 50 percent over current airfield mats.